Observed and Estimated Bycatch of Green Sturgeon in 2002–2015 US West Coast Groundfish Fisheries

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Executive Summary

The main purpose of this report is to update the previous analyses of green sturgeon bycatch in the U.S. West Coast groundfish fisheries with two additional years of observer data (2014-2015). The previous biennial green sturgeon bycatch report summarized bycatch information for the years of 2002-2013 (Lee et al. 2015). Although this report is a status update to the previous biennial report, this report is prepared as a standalone full report for the whole span of data series from 2002-2015.

Detailed analyses on the length frequencies of green sturgeon encountered, the depth distributions of hauls with green sturgeon bycatch, and the binomial model of encounter probabilities were not carried out for this status update report, because only a few additional years of data would not warrant any meaningful findings different from the ones in the previous report. If interested in detail results of those analyses, please refer to the previous biennial bycatch report (Lee et al. 2015).

In accordance with the National Marine Fisheries Service (NMFS) Biological Opinion on Continuing Operation of the Pacific Coast Groundfish Fishery (NMFS 2012, p. 126-127), this document provides an analysis of observed bycatch and fleet-wide take estimates of U.S. Endangered Species Act-listed green sturgeon (*Acipenser medirostris*) encountered in the U.S. west coast groundfish fisheries. Three federal groundfish fisheries and one state-managed fishery encountered green sturgeon between 2002 and 2015: limited entry (LE) bottom trawl fishery (2002-2010), Individual Fishing Quota (IFQ) bottom trawl fishery (2011-2015), at-sea hake fishery (A-SHOP; 2002-2015), and the state-managed California (CA) halibut bottom trawl fishery (2002-2015). It should be noted that "bycatch" in this report is defined as the discard of green sturgeon bycatch made at sea. The southern distinct population segment (Southern DPS) of North American green sturgeon was listed as threatened under the ESA in 2006. With the publication of the final 4(d) rule in the Federal Register in 2010, landings and sales of green sturgeon has been prohibited since the effective date of July 2, 2010 (75 FR 30714).

The Biological Opinion (NMFS 2012, aka BiOp) states that take of Southern DPS green sturgeon in the combined federally managed fisheries (e.g., LE groundfish bottom trawl, IFQ groundfish bottom trawl, and at-sea hake fisheries) should not exceed more than 28 fish per year. A summary of annual total bycatch of green sturgeon in the LE bottom trawl, IFQ bottom trawl, and A-SHOP sectors is given in Table 1.

While the BiOp only concerns Southern DPS as a listed species, currently there is no direct method to distinguish between Southern DPS and Northern DPS fish at the time of observation at sea. Based on data from the NWFSC Observer Programs, the take of all green sturgeon (regardless of DPS) in all federally-managed sectors combined (i.e., IFQ bottom trawl and A-SHOP) in the most recent five years was 38 in 2011, 22 in 2012, 10 in 2013, 40 in 2014, and 6 in 2015. It should be noted that these bycatch numbers are from fisheries with nearly 100% observer coverage.

Some of these bycatch samples were analyzed with genetic stock identification (GSI) technique to differentiate between Northern and Southern DPS fish (pers. comm. Dr. Carlos

Garza, SWFSC, NMFS). GSI analyses were able to assign the analyzed samples to each DPS origin. The results of GSI analyses also indicated that the proportions between the DPSs differed by the area of catch. 48% of green sturgeon caught off the Oregon (OR) and Washington (WA) coasts are mostly likely Southern DPS fish, whereas 95% of individuals caught off the CA coast are most likely Southern DPS fish. Based on the individual assignments and the estimated DPS proportions from the GSI analyses, the number of Southern DPS green sturgeon encountered in the federally-managed sectors in the most recent 5 years are estimated to be: 20 in 2011, 11 in 2012, 5 in 2013, 15 in 2014, and 3 in 2015. All of these estimates are below the authorized take level of 28 per year. However, the genetic stock identifications were available for only partial portions of bycatch samples for the years of 2007-14, and samples from 2015 observations are not analyzed with GSI yet at the point of writing this report. Thus, DPS proportions are subject to change with additional forthcoming data and should be interpreted with caution.

The BiOp only concerns federally-managed fisheries. However, the NWFSC West Coast Groundfish Observer Program (WCGOP) observes the state-managed California (CA) halibut fishery as well, which also encountered green sturgeon. We provide bycatch estimation of green sturgeon in this state-managed fishery as an appendix in this report to provide a more thorough understanding of the impacts of observed fisheries on this species.

Introduction

In accordance with the NMFS Biological Opinion on Continuing Operation of the Pacific Coast Groundfish Fishery (NMFS 2012, p. 126-127), this document provides an analysis of observed bycatch and fleet-wide take estimates of U.S. Endangered Species Act-listed green sturgeon (*Acipenser medirostris*) encountered in the U.S. west coast (Washington-Canada border to California-Mexico border) groundfish fishery sectors, observed from 2002-2015. The North American green sturgeon (hereafter referred to as "green sturgeon") is an anadromous fish. Within the sturgeon family Acipenseridae, green sturgeon is one of the most widely distributed and marine-oriented members, spending much of its life in the ocean (Moyle 2002). Green sturgeon occurs along the coastal waters of North America, ranging from northern Baja California to the Bering Sea (Mecklenberg et al. 2002). Depending on spawning locations and genetic distinctions, populations are classified into the Northern Distinct Population Segment (DPS) and the Southern DPS. The Southern DPS of green sturgeon was listed as threatened under the ESA in 2006 (71 FR 17757), and critical habitat was designated in 2009 (74 FR 52300).

This report includes green sturgeon bycatch estimates for all groundfish fisheries observed by the West Coast Groundfish Observer Program (WCGOP) and At-Sea Hake Observer Program (A-SHOP) from 2002 – 2015. We present observed green sturgeon bycatch (as number of individual fish) and bycatch ratio (as number of individual fish per metric ton of total target fish caught) per stratum. This bycatch ratio is then used to estimate fleet-wide total green sturgeon bycatch in each stratum, where only a portion of the total hauls were observed (2002-2010). Since the start of Catch Shares program in 2011, the IFQ fisheries have been observed at nearly 100% by onboard observers (except fishing operations under the Electronic Monitoring (EM) program in 2015). During that period (2011-2015), the observed bycatch represents almost all fleet-wide total bycatch although a tiny unsampled portion of total landings (generally less than 0.5%) had to be expanded for some strata.

The fishing trips under the Electronic Monitoring (EM) program, administered by the Pacific State Marine Fisheries Commission (PSMFC), should be considered as 100% monitored for green sturgeon bycatch. Only about 25% of fishing trips under the EM program are randomly selected for scientific data collection by onboard at-sea observer purposes (Somers et al. 2016). However, the EM Program of the PSMFC has actively monitored all EM video for green sturgeon bycatch to inform this bycatch status report. No green sturgeon bycatch was observed on the 2015 EM video system during fishing operations (Pers. Comm. Courtney Donovan, PSMFC).

This report does not include potential bycatch of green sturgeon in fisheries, even if there were any, for which those two observer programs did not cover or covered to a very limited degree. These fisheries include Tribal fisheries (except at-sea hake tribal), recreational fisheries, research fisheries, and fishing vessels operating under exempted fishing permits (EFPs).

Life History and Biology of Green Sturgeon

Green sturgeon are a long-lived, slow-growing, anadromous fish species. Green sturgeon spend 1 to 4 years in fresh and estuarine waters before making their first migration into ocean waters as sub-adults (Nakamoto et al. 1995). Green sturgeon spend the majority of their adult life in marine and estuarine environments, and migrates into rivers for spawning. The green sturgeon likely live up to 60 – 70 years (Moyle 2002). The size of adult green sturgeon ranges from 1.4 – 2 m in fork length (FL) for males and 1.6 – 2.2 m FL for females. Green sturgeon have long reproductive cycles with late maturity. Males reach maturity at about 14 – 16 years and females at 16 – 20 years, at which time they make their first spawning migration into freshwater (Van Eenennaam et al. 2006). Females return to freshwater to spawn every 2 – 4 years, and males potentially return to spawn every 1 – 3 years (Erickson and Webb 2007). Between spawning runs, green sturgeon migrate along the North American west coast, and can be found from Mexico to Alaska and Bering Sea. Green sturgeon are known to aggregate in coastal estuaries in Oregon and Washington (e.g., Columbia River estuary, Grays Harbor, Willapa Bay, and Winchester Bay) in the spring and summer months (Israel et al. 2004, Moser and Lindley 2007, Lindley et al. 2008, 2011). Due to the species' life history characteristics, wide distribution along the coast, and dependence on freshwater systems for spawning, green sturgeon are particularly susceptible to human-induced environmental changes, including impassible dams and barriers in spawning rivers, insufficient freshwater flows, chemical contaminants, and entrainment by water projects.

Based on genetic analyses and spawning site fidelity (Adams et al. 2002, Israel et al. 2004), at least two distinct population segments (DPS) have been identified for North American green sturgeon: a Northern DPS and a Southern DPS. The Northern DPS consists of populations originating from coastal watersheds northward of and including the Eel River, CA. The Northern DPS has been confirmed to spawn in two different river systems, the Rogue and Klamath-Trinity Rivers. The Southern DPS consists of populations originating from coastal watersheds southward of the Eel River, CA. The only known spawning population for the Southern DPS is in the Sacramento River system, making this population more vulnerable to catastrophic events. Northern DPS fish do not appear to occur in natal waters of the Southern DPS and vice versa. Outside of natal waters, however, the two distinct population segments overlap with one another. Because of this, green sturgeon observed in coastal bays, estuaries, and marine waters outside of natal waters could belong to either DPS. This is important because the Southern DPS is listed as threatened under the Endangered Species Act (ESA), whereas the Northern DPS is not (71 Fed. Reg. 17757; April 7, 2006). Because green sturgeon from the Northern and Southern DPS are morphologically indistinguishable, physical tagging or genetic data are needed to determine to which DPS an individual belongs.

Population abundance, status, and trends for the Northern and Southern DPS are not well known due to limited data. Preliminary data from Mora (2013) suggest that the adult spawning run size in the Klamath-Trinity and Rogue Rivers (Northern DPS) would be in the range of several hundreds and the spawning run size in the Sacramento River system would be less.

In marine waters, adults and subadults primarily occur at depths of 40-110 m (Erickson and Hightower 2007). Once green sturgeon enter coastal habitats after their freshwater life stages, they tend to migrate northward from their natal habitats (Erickson and Hightower 2007,

Lindley et al. 2008). Although green sturgeon are known to occur from Baja California to the Bering Sea (Mecklenburg et al. 2002), coastal marine waters from Monterey Bay to Vancouver Island are recognized as the primary migratory habitat (NMFS 2009). Green sturgeon are often found in aggregations in coastal bays and estuaries. In October of 2009, NMFS designated coastal marine waters within 60 fathoms (approximately 110 m) from Monterey Bay, CA to the Washington-Canada border as critical habitat for the Southern DPS (74 Fed. Reg. 52300). NMFS also designated the Sacramento River system and the adjacent estuaries as critical habitat, as well as several coastal estuaries in California, Oregon, and Washington (74 FR 52300).

Genetic and acoustic telemetry studies suggest that Northern DPS and Southern DPS fish co-occur in large concentrations in the Columbia River estuary, Grays Harbor, and Willapa Bay. The proportions of Southern DPS fish in those estuaries were found to be medium to high (41-81%), although they varied between years, between estuaries, and between the estimation methods (Israel et al. 2009).

Genetic analyses on green sturgeon bycatch samples for the years 2007-2014 indicated that the proportions of Southern DPS fish varied between years and fishing areas (pers. comm. Dr. Carlos Garza, SWFSC, NMFS, NOAA). When data are aggregated across the years, about 48% of the green sturgeon encountered and sampled off Oregon and Washington, and 95% of the green sturgeon encountered and sampled off the California coast likely belonged to the Southern DPS.

West Coast Groundfish Fishery

The west coast groundfish fishery (WCGF) is a multi-species fishery that utilizes a variety of gear types off the U.S. west coast between the Canada-Washington border and the California-Mexico border. The fishery harvests species designated in the Pacific Coast Groundfish Fishery Management Plan (FMP) and is managed by the Pacific Fishery Management Council (PFMC) (PFMC 2011). Over 90 species are listed in the groundfish FMP, including a variety of rockfish, flatfish, roundfish, skates, and sharks. These species are found in both federal (> 5.6 km off-shore) and state waters (0 - 5.6 km). For a complete list of groundfish species defined in the Pacific Coast Groundfish Fishery Management Plan, see PFMC (2011). Groundfish are both targeted and caught incidentally by trawl nets, hook-and-line gear, and fish pots. Under the FMP, the groundfish fishery consists of four management components:

The Limited Entry (LE) component encompasses all commercial fishers who hold a federal limited entry permit. The total number of limited entry permits available is restricted. Vessels with an LE permit are allocated a larger portion of the total allowable catch for commercially desirable species than vessels without an LE permit.

The Open Access (OA) component encompasses federal commercial fishers who do not hold a federal LE permit. Some states require fishers to carry a state issued permit for certain OA sectors.

The Recreational component includes recreational anglers who target or incidentally catch groundfish species. Recreational fisheries are not covered by this report.

The Tribal component includes native tribal commercial fishers in Washington State that have treaty rights to fish groundfish. Tribal fisheries are not included in this report, with the exception of the observed tribal at-sea Pacific hake (*Merluccius productus*) (also known as whiting) sector (see A-SHOP section in Table 1).

These four components can be further subdivided into sectors based on gear type, target species, permits and other regulatory factors. This report includes data from the following sectors:

Limited Entry (LE) sectors

Beginning in 2011, an Individual Fishing Quota (IFQ) program for the LE bottom trawl fleet and the at-sea Pacific hake fleet was implemented, under the West Coast Groundfish Trawl Catch Share Program.

- IFQ fishery (formerly LE bottom trawl and at-sea Pacific hake). The IFQ non-hake sectors consist primarily of bottom trawl, with some midwater trawl and gear-switching (fishing the IFQ permit using fixed gear). This sector is subdivided into the following components due to differences in gear type and target strategy. Components of the IFQ fishery during 2011–2014:
    - Bottom trawl: Bottom trawl nets are used to catch a variety of non-hake groundfish species. Catch is delivered to shore-based processors.
    - Midwater non-hake trawl: Midwater trawl nets are used to target midwater non-hake species. Catch is delivered to shore-based processors. Definition of the catch as occurring in this component is based on the captain's target as recorded in the logbook.
    - Pot: Pot gear is used to target groundfish species, primarily sablefish (*Anoplopoma fimbria*). Catch is delivered to shore-based processors.
    - Hook-and-line: Longlines are primarily used to target groundfish species, mainly sablefish. Catch is delivered to shore-based processors.
    - LE California halibut (*Paralichthys californicus*) trawl: Bottom trawl nets are used to target California halibut by fishers holding both a state California halibut permit and an LE federal trawl groundfish permit. Catch is delivered to shore-based processors.
    - At-sea motherships and catcher-processors: Midwater trawl nets are used to catch Pacific hake. Catcher vessels deliver unsorted catch to a mothership. The catch is sorted and processed aboard the mothership. Catcher-processors catch and process at-sea.
    - Tribal at-sea processing component of the Pacific hake sector. The tribal sector must operate within defined boundaries in waters off northwest Washington. Tribal catch can be delivered to a contracted mothership by catcher vessels for processing or be caught and processed by a contracted catcher-processor.
    - Shoreside midwater Pacific hake trawl: Midwater trawl nets used to catch Pacific hake. Catch is delivered to shore-based processors. Definition of the catch as occurring in this component is based on the captain's target as recorded in the logbook.

Beginning in 2015 some components of the IFQ fisheries are further divided into subcomponents for those vessels that participated in the EM program. For these fisheries, fishing operations and the bycatch of IFQ species are monitored by the EM system and shoreside Catch Monitors (CM), instead of onboard observers. In 2015, about 25% of fishing trips were randomly selected to be observed by onboard observers for scientific data collection purposes, such as bycatch sampling of non-IFQ species and biological sampling. Catch is delivered to shore-based processors. These sectors include IFQ EM–Bottom Trawl (for non-hake groundfish) and IFQ EM–Pot Gear fishery.

Beginning in 2015 the previously defined midwater non-hake trawl and the shoreside Pacific hake midwater trawl fisheries were redefined based on the proportion of Pacific hake in the catch in a trip:

- Shoreside midwater Pacific hake trawl (more than 50% of catch by a vessel on a given day is Pacific hake): Midwater trawl nets are used to catch Pacific hake. Catch is delivered to shore-based processors.
- Shoreside midwater rockfish trawl (less than 50% of catch by a vessel on a given day is Pacific hake): Midwater trawl nets are used to catch rockfish, typically widow and yellowtail. Catch is delivered to shore-based processors.

Open Access (OA) Federal sectors

- OA fixed gear (non-nearshore): Fixed gear, including longlines, pots, fishing poles, stick gear, etc. is used to target non-nearshore groundfish. Catch is delivered to shore-based processors.

Open Access (OA) state sectors

- OA ocean shrimp[2] (*Pandalus jordani*) trawl: Trawl nets are used to target ocean shrimp. Catch is delivered to shore-based processors.
- OA California halibut trawl: Trawl nets are used to target California halibut by fishers holding a state California halibut permit. Catch is delivered to shore-based processors.
- Nearshore fixed gear: A variety of fixed gear, including longlines, pots, fishing poles, stick gear, etc. are used to target nearshore rockfish and other nearshore species managed by state permits in Oregon and California. Catch is delivered to shore-based processors or sold live.

Northwest Fisheries Science Center Groundfish Observer Programs

The NWFSC Groundfish Observer Program's goal is to improve estimates of total catch and discard by observing commercial sectors of groundfish fisheries along the U.S. west coast that target or incidentally take groundfish as bycatch. The observer program has two units: the West Coast Groundfish Observer Program (WCGOP) and the At-Sea Hake Observer Program (A-SHOP). The WCGOP Program was established in May 2001 by NMFS, in accordance with the Pacific Coast Groundfish Fishery Management Plan (50 CFR Part 660) (50 FR 20609). This regulation requires all vessels that catch groundfish in the U.S. Exclusive Economic Zone (EEZ)

[2] *Pandalus jordani* is known as the ocean pink shrimp or smooth pink shrimp in Washington, pink shrimp in Oregon, and Pacific ocean shrimp in California. Herein we use the common name "ocean shrimp" in reference to *P. jordani* as suggested by the American Fisheries Society (McLaughlin et al. 2005).

from 3-200 miles offshore to carry an observer when notified to do so by NMFS or its designated agent. Subsequent state rule-making has extended NMFS's ability to require vessels fishing in the 0-3 mile state territorial zone to carry observers.

The WCGOP and A-SHOP observe distinct sectors of the groundfish fishery. The WCGOP observes the following federal groundfish sectors: IFQ shore-based delivery of groundfish and Pacific hake, LE and OA non-nearshore fixed gear; and the state-managed nearshore fixed gear sectors in OR and CA. The WCGOP also observes several state-managed fisheries that incidentally catch groundfish, including the California halibut trawl and ocean shrimp trawl fisheries. The A-SHOP observes the IFQ fishery that processes Pacific hake at sea including: catcher-processor, mothership, and tribal vessels. Details on how fishery observers operate in both the IFQ (aka Catch Shares) and Non-IFQ (aka Non-Catch Shares) sectors can be found online at: http://www.nwfsc.noaa.gov/research/divisions/fram/observation/index.cfm.

Groundfish Fishery Sectors with Green Sturgeon Bycatch

A summary of the permits, gear(s) used, target groups, vessel length range, fishing depth range, and management of fishery sectors and sub-sectors in U.S. west coast groundfish fisheries that have had documented green sturgeon bycatch is presented in Table 2. The following commercial groundfish fishery sectors had observed green sturgeon bycatch from 2002 – 2015:

Federally-managed sectors

- LE and IFQ bottom trawl fishery
- IFQ at-sea Pacific hake mothership fishery
- IFQ at-sea Pacific hake catcher-processor fishery
- IFQ at-sea Pacific hake tribal mothership

State-managed sectors

- LE & OA California halibut bottom trawl fisheries (see Appendix A)

Commercial groundfish fisheries observed by the WCGOP that did not have any observed bycatch of green sturgeon from 2002–2015 include:

- LE fixed gear primary sablefish
- LE fixed gear non-primary sablefish
- OA fixed gear
- Nearshore fixed gear state-permitted (Oregon and California)
- IFQ non-hake midwater trawl fishery (2011-2014)
- IFQ shoreside Pacific hake trawl (2011-2014)
- IFQ shoreside midwater Pacific hake trawl (2015)
- IFQ shoreside midwater rockfish trawl (2015)
- IFQ bottom trawl gear with electronic monitoring (EM) (2015)
- IFQ fixed gear with electronic monitoring (EM) (2015)
- OA ocean shrimp trawl

Green sturgeon bycatch off the U.S. west coast occurs in state operated commercial California (CA) halibut fishery sectors (LE and OA) in California, and the WCGOP observes these fisheries sectors. These CA halibut trawl fisheries are permitted by the state of California and are not regulated under the Pacific Coast Groundfish FMP, and therefore do not fall under the 2012 Biological Opinion for green sturgeon. Green sturgeon bycatch in these CA halibut trawl fisheries is important to understand from the perspective of species conservation. However, to clearly define the scope of the reporting required under the 2012 Biological Opinion, green sturgeon bycatch in CA halibut fisheries is reported in Appendix A and will not be further covered in the body of the current document. Recommendations to the PFMC regarding green sturgeon under the Biological Opinion should not include the CA halibut fisheries.

Amount and Extent of Take

The Biological Opinion (BiOp) on Continuing Operation of the Pacific Coast Groundfish Fishery (NMFS 2012, p. 121-122) stated that:

> "… take of threatened Southern DPS green sturgeon will occur as a result of the continued operation of the Pacific Coast groundfish fishery. Incidental take of Southern DPS green sturgeon is expected to occur as a result of incidental capture and handling in the fishery, mortalities resulting from encounter with fishing gear and/or removal of captured fish from the water, and handling by the NMFS observer program. Under the proposed action, incidental take of Southern DPS green sturgeon because of bycatch and handling in the fishery is not expected to exceed 28 fish per year; however, we recognize the potential for incidental take of greater numbers of Southern DPS green sturgeon in some years. Therefore, this take statement allows for incidental take of up to 86 Southern DPS green sturgeon per year in no more than 2 years within a period of 9 consecutive years."

The current document presents WCGOP and A-SHOP data on bycatch of green sturgeon (in number of individuals) in the U.S. west coast groundfish fisheries covered by the Pacific Coast Groundfish FMP. While ESA-listing and BiOp statements are only relevant to Southern DPS green sturgeon, the bycatch information in this report includes both Northern and Southern DPS green sturgeon, because an identification of DPS is not possible during at-sea observations and the current observer data do not have information on the DPS origin of individual green sturgeon. However, based on the GSI-based individual assignments and the proportion of Southern DPS bycatch from the GSI analyses (see Life History section above), the take of Southern DPS are estimated per year.

At the present time, we have no information on the recapture rate of the same individual green sturgeon or level of mortality of green sturgeon after being caught, landed on the deck, observed, handled, and released by observers in U.S. west coast groundfish fisheries. Green sturgeon tagging studies have been conducted in the recent years, thus more information on post-release mortalities and recapture rates would be available in the near future.

Materials and Methods

Data Sources

Data sources for this analysis include onboard observer data from the WCGOP and A-SHOP and landing receipt data (a.k.a. fish tickets), obtained from the Pacific Fisheries Information Network (PacFIN).

Observer data

To date, observer data is the sole source for at-sea discard estimation in U.S. west coast groundfish fisheries. A list of fisheries, coverage priorities and data collection methods employed by WCGOP in each observed fishery can be found in the Catch Shares (aka IFQ) and Non-Catch Shares (aka Non-IFQ) WCGOP manual (NWFSC 2017). A-SHOP program information and documentation on data collection methods can be found in the A-SHOP observer manual (NWFSC 2016).

The sampling protocol employed by the WCGOP is primarily focused on the discarded portion of catch. To ensure that the recorded weights for the retained portion of the observed catch are accurate, haul-level retained catch weights recorded by observers are adjusted based on trip-level fish ticket records. This process is described in further detail on the WCGOP Data Processing webpage (http://www.nwfsc.noaa.gov/research/divisions/fram/observation/data_processing.cfm). Data processing was applied prior to the analyses presented in this report.

When green sturgeon are encountered on vessels, observers document fish length (in fork length), weight, and general condition, take photographs, scan for scute markings and tags, and take a tissue sample. If the specimen is obviously dead, the observer will also take a fin ray sample and determine sex (NWFSC 2016).

Fish ticket data

The retained landing information from fish tickets (sales receipts) provides an effort metric of the landed amount of a particular fish species or group, and is necessary to estimate fleet-wide total bycatch for sectors of the west coast groundfish fishery with less than 100% observer coverage. Fish tickets are completed by fish-buyers in each port for each delivery of fish by a vessel. Fish tickets are trip-aggregated sales receipts for market categories that may represent single or multiple species. Fish tickets are issued to fish-buyers by a state agency and must be returned to the agency for processing. Fish tickets are designed by the individual states (Washington, Oregon, and California) with slightly different format in each state. In addition, each state conducts species-composition sampling at the ports for numerous market categories that are reported on fish tickets. Fish ticket and species-composition data are submitted by state agencies to the PacFIN regional database. Observer and fish ticket data processing steps are described in detail on the WCGOP website under Data Processing Appendix (http://www.nwfsc.noaa.gov/research/divisions/fram/observer/data_processing.cfm/). All data processing steps specific to this report are described in the bycatch estimation methods section below.

Bycatch Estimation Methods

The landed amount of a target species (or species groups) was used as a proxy for fishing effort. The choice of target species and therefore, the effort metric, depends on fishery sector. Thus, green sturgeon bycatch was estimated for each individual fishery sector. Target species of those sectors that encountered green sturgeon during 2002–2015 were: all FMP-managed groundfish species except Pacific hake for LE bottom trawl and IFQ trawl sectors, and Pacific hake for at-sea hake fisheries.

LE bottom trawl fishery

The LE bottom trawl fishery was a multi-species fishery (2002–2010) that targeted various groundfish species. Since 2011, this fishery has been managed under an Individual Fishing Quota (IFQ) system. The data were stratified by year, state of landing, and season for bycatch estimation, as done in the previous biennial BiOp bycatch report (Lee et al. 2015). Months of January-April and November-December are defined as winter, and May-October as summer. LE bottom trawl vessels can hold a California halibut bottom trawl permit and participate in the state-permitted California halibut fishery. California halibut tows can occur on the same trip as tows targeting groundfish and were identified based on the following criteria: 1) the reported tow target was California halibut or 2) the tow target was nearshore mix, sand sole, or other flatfish, and the tow took place in less than 30 fathoms and south of 40°10' N. latitude. All tows in the observer data that met at least one of these two requirements were removed from the LE bottom trawl data and included in the California halibut trawl data (see Appendix A).

A ratio estimator was used to estimate the fleet-wide total number of green sturgeon catch per stratum for the LE sector, in which only a portion of fishing vessels were observed out of all fishing vessels that participated in the sector. A bycatch ratio (aka, bycatch rate) per stratum was computed from observer data as the observed catch of green sturgeon (number of individuals) divided by the observed retained weight of target species (or species groups). Total green sturgeon bycatch at the fleet-wide level was then estimated based on the simple expansion of the bycatch ratio by the total targeted fish landings, as the expansion factor, for a given strata. The estimation of bycatch ratio and fleet-wide expansion were done according to the following equation:

$$\hat{D}_s = \frac{\sum_t d_{st}}{\sum_t r_{st}} \times F_s$$

where:

s = individual stratum (a combination of sector, year, season, state)
t = individual tows
d = observed bycatch of green sturgeon (number of individuals)
r = observed retained weight of target species or species group
F = total weight of landed target species recorded on fish tickets
$\hat{D}$ = fleet-wide total bycatch estimate of green sturgeon

Catch Shares: IFQ bottom trawl fishery

Since 2011, the U.S. west coast LE groundfish trawl fishery has been managed under the Catch Shares Program, which led to the establishment of Individual Fishing Quotas (IFQs). Under this program, all participating vessels are required to carry a WCGOP observer on all fishing trips, resulting in 100% observer coverage. In addition, permit holders with IFQ and a trawl endorsement can fish multiple gear types (although not within the same trip), including bottom or midwater trawl, hook and line, or pot gear. Green sturgeon were encountered only in the IFQ bottom trawl gear sector. Fleet-wide green sturgeon bycatch for this sector is almost completely known because all vessels carry an observer, resulting in a complete census. Bycatch for this fishery was summarized by year and state of landing.

All Catch Shares fishing trips are observed by at-sea observers (except EM fishing trips as described in the Introduction), but a very small number of tows or a small portion of catch from a given tow may be unsampled due to observer illness or other circumstances. Overall the unsampled catch was very small, comprising less than 0.5% of the total landed weight of IFQ species during 2011–2015. Four types of unsampled catch categories can occur during observed trips: completely unsorted catch (discards and retained), unsampled discards, unsampled non-IFQ species and failed data. Both completely unsorted catch and unsampled discard could contain both IFQ and non-IFQ species, but unsampled non-IFQ species only contains species that do not belong to the IFQ species list. Data is classified as failed if observer's sampling errors are consistently found in a haul or trip, although the landing quantities of retained catches are known from the associated fish ticket data for this data category. Estimates of green sturgeon bycatch for unsampled portion are derived per each unsampled category type separately. Estimated bycatch from the unsampled portion of the catch is then added to the observed bycatch amount to obtain the total bycatch estimate. Expansion for the unsampled portion was only needed if green sturgeon were encountered within a stratum. If no green sturgeon were encountered in a stratum, then it was assumed that no green sturgeon were encountered in the unsampled catch. The following equation was used to estimate bycatch in the unsampled portions of the catch in IFQ fisheries:

$$\hat{U}_{sc} = \frac{\sum_{t} d_{st}}{\sum_{t} w_{sct}} \times Z_{sc}$$

where:

s = stratum (a combination of sector, year, season, state)
c = category of unsampled catch (unsorted, discards, non-IFQ, or failed)
t = individual tows
d = observed bycatch of green sturgeon (number of individuals)
w = weight of sampled catch
Z = weight of unsampled catch (i.e., the expansion factor)
$\hat{U}$ = bycatch estimate of green sturgeon in unsampled catch

Green sturgeon bycatch was estimated within unsorted catch by multiplying the bycatch ratio (i.e., the number of green sturgeon in a given stratum divided by the sum of the sampled weight for all species (discarded and retained) by the sum of the weight of unsorted catch of all species within the stratum (i.e., expansion factor). Estimations for other unsampled categories were done in a similar manner, but with different denominators for the bycatch ratio and different expansion factors. For the unsampled discard category, the denominator was the sum of the sampled weight of all discarded species (IFQ and non-IFQ species) and the expansion factor was the unsampled weight of all discarded species. For the unsampled non-IFQ category, the denominator was the sum of the sampled weight of all discarded non-IFQ species and the expansion factor was the sum of the unsampled weight of discarded non-IFQ species. For the failed data category, the denominator was the sum of the landed weight of all FMP-listed groudfish (except hake) and the expansion factor was the sum of the unsampled landed weight of all FMP-listed groundfish (except hake) within the stratum.

It should be noted that the overall portion of these unsampled data categories that need an expansion is a very small fraction (generally less than 0.5%) relative to sampled portion in the Catch Shares fishery sectors. Thus, the observed green sturgeon bycatch in the Catch Share sector should precisely represent the fleet-wide total bycatch amount in most strata.

At-sea Pacific hake fishery

Observed and expanded bycatch data were provided directly from the A-SHOP and incorporated into this report. The green sturgeon bycatch is reported by year and by each at-sea hake fishery sector: catcher-processors, motherships, and tribal catch delivered at-sea. All vessels fishing in the at-sea hake fishery carry two A-SHOP observers for every fishing day (i.e., 100% coverage).

Even though very rare, entire hauls may not be sampled due to unforeseen circumstances (e.g., sickness of observers). These unsampled hauls need to be expanded at the strata level. Typically, greater than 99% of hauls are sampled each year, thus the unsampled portion that needs expansion is a very small fraction.

The green sturgeon catch in unsampled hauls is estimated by multiplying the green sturgeon catch from the sampled weight by the proportion of unsampled weight over the total weight per given stratum. This estimated green sturgeon catch for unsampled hauls is then added to the sum of all green sturgeon catch in the sampled hauls to produce the total estimated green sturgeon bycatch per given strata. The total number of green sturgeon caught by the at-sea hake fleet per given stratum was calculated using the following formula:

$$B_s = \sum Y_{st} + \sum Y_{st} \cdot \left(\frac{U_s}{T_s}\right)$$

where:

B = the total estimated green sturgeon bycatch
s = individual stratum

t = individual tow
Y = observed number of green sturgeon bycatch
U = weight of unsampled hauls
T = weight of sampled hauls

Measures of Uncertainty

As a measure of uncertainty for the estimated bycatch ratio, upper and lower limits of the 95% confidence interval were estimated with a non-parametric bootstrap procedure for each stratum if the fishery was not 100% observed (i.e., non-IFQ fisheries). The bootstrap procedure randomly selects vessels that were observed within a stratum, with replacement. The number of vessels randomly selected is the same as the total number of observed vessels in the stratum. Random selection of vessels is intended to approximate the WCGOP vessel selection process. The bycatch ratio was estimated for each of 10,000 bootstrapped data sets to obtain a bootstrapped distribution of bycatch ratio estimates. The lower (2.5% percentile) and upper (97.5% percentile) confidence limits of the bycatch ratio were calculated from the bootstrapped distribution. The 95% confidence interval was also estimated for the fleet-wide bycatch estimate per stratum by multiplying the confidence limits of the bycatch ratio by total landed weight of the target species in a given stratum. The lower confidence bound of the total fleet-wide bycatch estimate was truncated at the observed bycatch amount if the estimated lower bound was less than the observed bycatch amount.

Data confidentiality required that we pooled the strata over a three year time window to estimate and report bycatch for certain strata (i.e., < 3 observed vessels per strata). If there were fewer than three observed vessels in a given stratum, data confidentiality prohibits revealing catch and other associated fishing trip information in that stratum. To overcome these issues, we pooled strata from the year before, the year of, and the year after the confidential stratum. We then applied a bootstrapping procedure, as mentioned above, to the three-year pooled strata to estimate the bycatch ratio and its confidence limits in the confidential stratum. The average of bootstrapped ratios was calculated as the estimated bycatch ratio in the confidential stratum. This bycatch ratio can be viewed as a three-year running average. Among the federally managed sectors that encountered green sturgeon during 2002–2015, only one confidential stratum occurred, the winter season of 2008 in the Washington LE bottom trawl fishery sector.

Observer Sampling Rate

Observer sampling rate per stratum was defined as the percent of observed fishing effort (i.e., landed weight of target species sampled by observers) over total fishing effort (i.e. fleet-wide landed weight of target species). A distinction between observer coverage and observer sampling rate should be noted. Since the start of Catch Shares (i.e., IFQ) program, all fishing trips are required to carry at least one at-sea observer, hence all the catches would be observed with a target sampling rate at 100% level under the Catch Shares program, unless the vessels are exempted from carrying onboard observers due to EM systems in 2015. However, due to unforeseen events, such as observer's sickness, some hauls may not be sampled. Thus, sampling rate may not reach a target of 100%. The exemptions from having onboard observers for all fishing trips are made if vessels are permitted to operate under the electronic monitoring (EM)

program. About 25% of fishing trips participating in the EM program in 2015 were observed by the WCGOP for scientific sampling purposes.

Results

Green Sturgeon Bycatch

Observer data indicated that fishing operations of the LE and IFQ bottom trawl sectors were geographically very extensive (Fig. 1). Fishing extended broadly north to south from the U.S.–Canada to the U.S.–Mexican boundaries. The map also shows that observed green sturgeon bycatch mostly occurred in confined shallow coastal waters off Astoria, OR, around the Columbia River outflow. However, note that green sturgeon bycatch would have occurred in unobserved fishing locations for the years 2002 to 2010, during which observer coverages were about 20%.

Summaries of green sturgeon encounters in the U.S. West Coast groundfish fishery sectors that were observed by WCGOP and A-SHOP between 2002 and 2015 are provided for the LE bottom trawl sector (2002-2010; Table 3), the IFQ bottom trawl sector (2011-2015; Table 4), and the at-sea hake fisheries sectors (2002-2015; Table 5). Considering the extent of fishing operations over broad latitudinal areas and depth zones (Fig. 1), green sturgeon bycatch in the LE bottom trawl sector were very few and sporadic, with mostly zero encounters within strata (Table 3). The highest observed bycatch was 6 green sturgeon in the summer of 2009, which resulted in a fleet-wide expanded bycatch estimate of 25 green sturgeon in that stratum. In the IFQ bottom trawl sector, the estimated fleet-wide total bycatch ranged between 6 and 40 green sturgeon during 2011-2015 (Table 4). Although the total fishing effort, estimated based on the total landed weight of all FMP groundfish (except Pacific hake), was relatively constant over this period, green sturgeon bycatch varied without a clear trend. The at-sea hake trawl fishery rarely encountered green sturgeon, with 1 fish in 2005 and 2 fish in 2006, from 2002-2015 (Table 5).

Genetic Stock Identification

Tissue samples were collected by the at-sea observers when green sturgeon were encountered in the fishery sectors. Green sturgeon tissue sampling by observers was set with a target of 100% since 2011. The tissue samples were analyzed with a GSI technique by Dr. Carlos Garza (SFWC, NMFS, NOAA), and the GSI data were shared with the authors of this report (Table 6). In theory, if tissue samples for all green sturgeon observed in the Catch Shares fishery sectors (nearly 100% observer coverages) were collected, genetically analyzed, and individually assigned for their DPS origins, then the exact number of SDPS bycatch per stratum would have been available to the authors without a need for further estimation. However, not all bycatch samples were genetically analyzed and individually identified for its DPS origin, although a substantial portion of bycatch samples were analyzed. Genetic samples from year 2015 were not yet processed and analyzed at the time of writing this report. The overall proportion of SDPS was 48% for those bycatch samples (n = 89) collected off Columbia River/Willapa Bay/Grays Harbor areas in the LE and Catch Shares-bottom trawl fishery sectors, when calculated across the years 2007-2014. The proportion of SDPS was 95% for those green sturgeon bycatch samples (n = 118) caught off San Francisco Bay/Half Moon Bay from the California halibut

fishery sectors between 2007-2014 (See Table A6 in the Appendix). Thus, for Catch Shares bycatch data, the number of bycatch samples with unknown DPS origin was multiplied by 48% for Washington and Oregon bycatch, and multiplied by 95% for California bycatch to estimate the SDPS numbers per stratum. For example, GSI assignments were not available for 10 individuals out of 38.4 total expanded bycatch numbers from the Catch Shares bottom trawl in Oregon in 2014. Total expanded bycatch number for the Catch Shares bottom trawl in Oregon in 2014 was estimated to be 38.4 after accounting for unsampled catch categories (Table 4). Refer to Methods section for the definition of unsampled catch categories. GSI assignments were not available for 11.4 individuals out of 38.4 individuals (Table 6). Based on SDPS proportion for this area (48%), the number of SDPS in the green sturgeon bycatch samples without individual GSI assignments was estimated to be 5.47 individuals. Thus, after rounding 20.47 to the nearest integer, the total number of SDPS for this stratum is estimated to be 20 individuals (15 estimated from GSI individual assignments, 5.47 estimated from SDPS proportion).

Observer Sampling Rate

The extent of observer sampling rates differed by fishery sectors. Sampling rates for the LE bottom trawl sector ranged between 7.2% - 38.3% at strata level, with an average of 19.7%, during 2002-2010 (Table 3). For IFQ bottom trawl sector, sampling rates ranged between 98.5% - 100%, with an average of 99.6% (Table 4).

In 2015, the groundfish landings made by those vessels participating in the EM-Bottom Trawl sector accounted for only a small fraction (2.53%) of total landings by Catch Shares bottom trawl fishery sectors (Somers et al. 2016). Based on an agreement between the WCGOP and the EM Program of the PSMFC, any green sturgeon bycatch would be carefully reviewed and recorded by EM video reviewers, and the bycatch data would be shared with the WCGOP if such events occurred. Thus, the Catch Shares fishery sectors, including the EM program, should be regarded as 100% monitored fishery sectors for green sturgeon bycatch. No green sturgeon bycatch was reported in the EM fisheries in 2015, based on the observations by the WCGOP and by the EM Program.

Discussion

The Biological Opinion (NMFS 2012, p. 122, aka BiOp) states that take of Southern DPS in the combined LE groundfish bottom trawl, IFQ groundfish bottom trawl, and at-sea hake fisheries should not exceed more than 28 fish per year. With the help of GSI analyses, the SDPS bycatch numbers were reliably estimated per stratum. When SPDS bycatch estimates are combined across the federally-managed fishery sectors, there was no single year that exceeded the annual limit (28 fish per year) for the years of observations (2002-2015).

With the implementation of the catch shares program beginning in 2011, the IFQ bottom trawl fishery sector has been observed at sea with 100% coverage. The at-sea hake trawl sector has been observed at 100% as well. Thus, the observed green sturgeon bycatch should be a nearly complete census of all green sturgeon bycatch across all fishing vessels in these federally-managed fishery sectors for 2011-2015. With more GSI analyses in future years, the individual green sturgeon bycatch from these sectors will be more accurately assigned to the Northern or

Southern DPS. Hence, the estimated number of Southern DPS green sturgeon bycatch in these fisheries will become more accurate.

Bycatch estimates, stratified by state and year, should be interpreted with caution in terms of area stratification. For the West Coast, the bycatch has been traditionally estimated and summarized by state of landings (or management lines) based on the return port for reliable expansion. This was because the landed amount of target species has been used as an expansion factor (i.e., total fishing effort) that could be reliably verified by fish ticket information. The stratification by state lines (i.e., state of landing) does not necessarily match with the actual locations of bycatch encounters. For example, it would be very possible that catches from the fishing off the southern Washington coast were landed in a northern port of Oregon. In this case, the bycatch would be summarized as being encountered in Oregon, instead of actual location of southern Washington. Because the Catch Shares are observed at nearly 100%, it should be examined whether actual encounter locations would serve better than state lines for a latitudinal stratification for the next biennial report. If actual encounter locations are used for area stratifications, the application of GSI assignments and SDPS proportions by area would become more accurate.

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Table 1. Summary of expanded bycatch numbers of green sturgeon in limited entry bottom trawl (LE) and IFQ bottom trawl (IFQ) sectors, by state (WA = Washington, OR = Oregon, and CA = California), that were observed by the WCGOP, and three sectors of the at-sea hake fishery that were observed by the A-SHOP (CP = Catcher Processor, MS = Non-Tribal Mothership, TM = Tribal Mothership) during 2002-2015. Estimates of Southern DPS (SDPS) bycatch are calculated based on individual assignments of genetic stock identification (GSI) and GSI proportions by catch areas (48% for WA and OR, 95% for CA). NDPS indicates Northern DPS populations. Fishery sectors under observations, but never encountered green sturgeon for 2002-2015 (e.g., federal open access sectors), are omitted from the table for clarity.

WCGOP

		State			SDPS (48%)		SDPS (95%)	Totals	
Sector	Year	WA	OR	CA	WA	OR	CA	Both DPS	SDPS
LE	2002	0	13	7	0	6.3	6.7	20	13
	2003	0	0	0	0	0	0	0	0
	2004	5	5	0	2.4	2.4	0	10	5
	2005	0	5	0	0	2.4	0	5	2
	2006	0	0	0	0	0	0	0	0
	2007	0	6	0	0	2.9	0	6	3
	2008	0	0	0	0	0	0	0	0
	2009	6	37	0	2.9	17.9	0	43	21
	2010	0	8	0	0	3.9	0	8	4
IFQ	2011	0	38	0	0	20.5	0	38	20
	2012	0	22	0	0	10.7	0	22	11
	2013	0	10	0	0	5.5	0	10	5
	2014	0	40	0	0	14.6	0	40	15
	2015	0	5	1	0	2.5	1.0	6	3

A-SHOP

	Sector			SDPS (48%)			Totals	
Year	CP	MS	TM	CP	MS	TM	Both DPS	SDPS
2002	0	0	0	0	0	0	0	0
2003	0	0	0	0	0	0	0	0
2004	0	0	0	0	0	0	0	0
2005	0	0	1	0	0	0.5	1	0
2006	0	2	0	0	0.96	0	2	1
2007	0	0	0	0	0	0	0	0
2008	0	0	0	0	0	0	0	0
2009	0	0	0	0	0	0	0	0
2010	0	0	0	0	0	0	0	0
2011	0	0	0	0	0	0	0	0
2012	0	0	0	0	0	0	0	0
2013	0	0	na	0	0	na	0	0
2014	0	0	na	0	0	na	0	0
2015	0	0	na	0	0	na	0	0

Table 2. Generalized descriptions of U.S. west coast groundfish fisheries that have had observed bycatch of green sturgeon (2002-2015).

							Management	
Sector	**Sub-Sector**	**Permits**	**Gear(s)**	**Target(s)**	**Vessel length (m)**	**Depths (m)**	**2002-2010**	**2011-2015**
Limited Entry (LE) Trawl		Federal LE permit with trawl endorsement	Bottom trawl, Midwater trawl	Groundfish assemblage	11–29	Wide range	Cumulative two month trip limits; depth-based closures; 14-23% observer coverage	Individual Fishing Quotas (IFQ); 100% observer coverage or EM
At-Sea Hake	Mothership-Catcher Vessel (MSCV)	LE permit with MSCV endorsement	Midwater trawl	Pacific hake	26–45	53–460	Seasonal quotas for target and bycatch species of concern; 100% observer coverage	IFQ; seasonal; 100% observer
	Catcher-processors (CP)	LE permit with CP endorsement	Midwater trawl	Pacific hake	82–115	60–570	Same as At-Sea Hake MSCV	IFQ; seasonal; 100% observer
	Tribal	(none)	Midwater trawl	Pacific hake		53–460	Tribal; 100% observer coverage	Tribal; 100% observer coverage
Shoreside Hake / Rockfish		LE permit with trawl endorsement	Midwater trawl	Pacific hake	17–29	Wide range	Same as At-Sea Hake MSCV; Some EM	IFQ; Seasonal; 100% observer coverage or EM

Table 3. Observed bycatch numbers, bycatch ratios, and fleet-wide total bycatch estimates of green sturgeon from limited entry bottom trawl fishery (2002-2010). Bootstrapped confidence intervals (95% CI) are provided for the estimates. Groundfish landings are in metric tons (MT). Winter season is January-April and November-December; summer is May-October. Asterisks (*) signify confidential strata with fewer than three observed vessels. Because of limited decimal points in the table, bycatch ratios for some strata are shown as zeros (0.00) although they are positive numbers (> 0.00). These positive but small bycatch ratios have numeric confidence intervals, rather than "na".

Washington

Year	Season	Observed bycatch	Observed groundfish landings (MT)	Fleet-total groundfish landings (MT)	Groundfish landings sampled (%)	Bycatch ratio	Lower CI of ratio	Upper CI of ratio	Fleet-total bycatch	Lower CI of bycatch	Upper CI of bycatch
2002	winter	0	318.2	1332.4	23.9	0.00	na	na	0	na	na
	summer	1	155.9	1089.6	14.3	0.01	0.00	0.02	7	1	25
2003	winter	0	132.7	1371.0	9.7	0.00	na	na	0	na	na
	summer	0	59.1	674.2	8.8	0.00	na	na	0	na	na
2004	winter	0	343.3	895.7	38.3	0.00	na	na	0	na	na
	summer	0	188.5	958.3	19.7	0.00	na	na	0	na	na
2005	winter	0	174.2	1004.3	17.3	0.00	na	na	0	na	na
	summer	0	426.5	2026.3	21.1	0.00	na	na	0	na	na
2006	winter	0	92.2	528.0	17.5	0.00	na	na	0	na	na
	summer	0	304.9	1317.6	23.1	0.00	na	na	0	na	na
2007	winter	0	170.9	723.1	23.6	0.00	na	na	0	na	na
	summer	0	63.6	879.7	7.2	0.00	na	na	0	na	na
2008	winter	*	*	794.0	*	0.00	0.00	0.00	0	0	0
	summer	0	324.4	931.2	34.8	0.00	na	na	0	na	na
2009	winter	0	366.6	1415.3	25.9	0.00	na	na	0	na	na
	summer	0	397.0	1274.0	31.2	0.00	na	na	0	na	na
2010	winter	0	282.5	1237.3	22.8	0.00	na	na	0	na	na
	summer	0	221.9	891.6	24.9	0.00	na	na	0	na	na

Table 3. Continued.

Oregon

Year	Season	Observed bycatch	Observed groundfish landings (MT)	Fleet-total groundfish landings (MT)	Groundfish landings sampled (%)	Bycatch ratio	Lower CI of ratio	Upper CI of ratio	Fleet-total bycatch	Lower CI of bycatch	Upper CI of bycatch
2002	winter	1	654.1	4288.8	15.3	0.00	0.00	0.01	7	1	23
	summer	1	538.0	3645.4	14.8	0.00	0.00	0.01	7	1	19
2003	winter	0	898.2	4667.3	19.2	0.00	na	na	0	na	na
	summer	0	576.1	4625.5	12.5	0.00	na	na	0	na	na
2004	winter	0	1230.3	4555.0	27.0	0.00	na	na	0	na	na
	summer	1	1032.7	5449.7	18.9	0.00	0.00	0.00	5	1	17
2005	winter	0	1268.8	4850.8	26.2	0.00	na	na	0	na	na
	summer	1	1271.9	5826.4	21.8	0.00	0.00	0.00	5	1	14
2006	winter	0	855.4	4347.9	19.7	0.00	na	na	0	na	na
	summer	0	1215.7	6644.1	18.3	0.00	na	na	0	na	na
2007	winter	0	877.4	6158.9	14.2	0.00	na	na	0	na	na
	summer	1	1199.4	6598.0	18.2	0.00	0.00	0.00	6	1	18
2008	winter	0	1401.0	7999.9	17.5	0.00	na	na	0	na	na
	summer	0	1922.9	7868.0	24.4	0.00	na	na	0	na	na
2009	winter	3	2204.7	9030.6	24.4	0.00	0.00	0.00	12	3	42
	summer	6	1901.7	7984.5	23.8	0.00	0.00	0.01	25	6	65
2010	winter	0	902.7	7488.3	12.1	0.00	na	na	0	na	na
	summer	2	1843.7	7512.0	24.5	0.00	0.00	0.00	8	2	20

California

Year	Season	Observed bycatch	Observed groundfish landings (MT)	Fleet-total groundfish landings (MT)	Groundfish landings sampled (%)	Bycatch ratio	Lower CI of ratio	Upper CI of ratio	Fleet-total bycatch	Lower CI of bycatch	Upper CI of bycatch
2002	winter	0	480.3	3758.7	12.8	0.00	na	na	0	na	na
	summer	0	533.5	3890.4	13.7	0.00	na	na	0	na	na
2003	winter	0	342.1	2925.5	11.7	0.00	na	na	0	na	na
	summer	0	582.1	4125.3	14.1	0.00	na	na	0	na	na
2004	winter	0	742.8	2193.5	33.9	0.00	na	na	0	na	na
	summer	1	772.1	3621.8	21.3	0.00	0.00	0.00	5	1	14
2005	winter	0	503.4	2492.0	20.2	0.00	na	na	0	na	na
	summer	0	596.6	3086.3	19.3	0.00	na	na	0	na	na
2006	winter	0	367.9	1926.7	19.1	0.00	na	na	0	na	na
	summer	0	607.3	3030.6	20.0	0.00	na	na	0	na	na
2007	winter	0	427.8	2377.5	18.0	0.00	na	na	0	na	na
	summer	0	703.1	3705.3	19.0	0.00	na	na	0	na	na
2008	winter	0	575.6	3179.3	18.1	0.00	na	na	0	na	na
	summer	0	663.2	3415.8	19.4	0.00	na	na	0	na	na
2009	winter	0	546.4	2832.3	19.3	0.00	na	na	0	na	na
	summer	1	637.0	3518.8	18.1	0.00	0.00	0.00	6	1	18
2010	winter	0	203.8	2133.8	9.5	0.00	na	na	0	na	na
	summer	0	565.0	3057.8	18.5	0.00	na	na	0	na	na

Table 4. Observed and fleet-wide total expanded numbers of green sturgeon bycatch from the IFQ bottom trawl fishery (2011-2015) (WA = Washington, OR = Oregon, and CA = California). Groundfish landings are in metric tons. Note that the IFQ fisheries are sampled at close to 100%.

State	Year	Observed bycatch	Observed groundfish landings (MT)	Fleet-total groundfish landings (MT)	Groundfish landings sampled (%)	Estimated bycatch from unsampled catch	Fleet-total bycatch
WA	2011	0	1849.3	1859.6	99.4	0	0
	2012	0	2096.2	2127.5	98.5	0	0
	2013	0	1486.9	1488.7	99.9	0	0
	2014	0	736.9	739.6	99.6	0	0
	2015	0	409.2	409.2	100.0	0	0
OR	2011	37	10795.7	10876.7	99.3	1.4	38.4
	2012	21	10625.4	10692.1	99.4	0.5	21.5
	2013	10	12098.2	12133.5	99.7	0.3	10.3
	2014	39	10431.3	10494.7	99.4	0.7	39.7
	2015	5	11036.0	11085.7	99.6	0.1	5.1
CA	2011	0	4596.6	4601.9	99.9	0	0
	2012	0	4443.0	4451.5	99.8	0	0
	2013	0	5029.9	5043.7	99.7	0	0
	2014	0	4855.3	4880.0	99.5	0	0
	2015	1	4096.2	4098.9	99.9	0.0	1.0

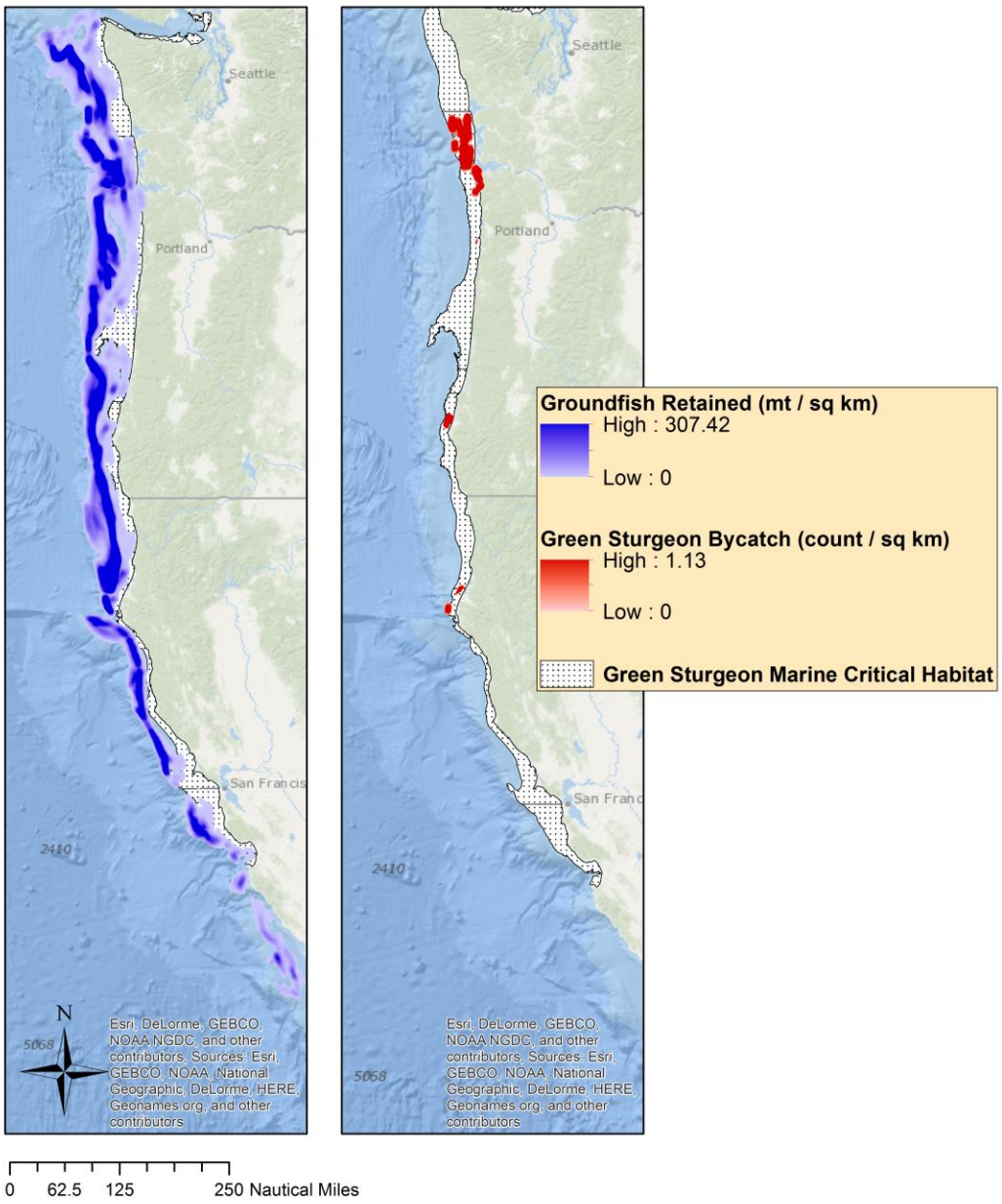
Table 5. Observed and expanded bycatch numbers of green sturgeon from the At-Sea hake fishery (2002-2015). Hake landings are shown in metric tons. Note that this fishery is sampled at close to 100%. The tribal mothership sector did not participate in this fishery in 2013-15. Asterisks (*) signify confidential strata with fewer than three observed vessels.

Sector	Year	Observed bycatch	Fleetwide Expanded bycatch	Sampled tow numbers	Sampled hake landings (MT)	% tows sampled
Catcher Processor	2002	0	0	556	36332.9	99.8
	2003	0	0	766	41468.6	99.9
	2004	0	0	1492	72858.7	99.7
	2005	0	0	1332	78497.5	99.9
	2006	0	0	1488	78246.3	99.9
	2007	0	0	1566	72898.1	99.7
	2008	0	0	1864	107754.4	99.0
	2009	0	0	863	34590.8	100.0
	2010	0	0	1063	54217.3	99.9
	2011	0	0	1530	71336.7	99.7
	2012	0	0	1100	55522.6	99.8
	2013	0	0	1439	78004.8	99.7
	2014	0	0	1683	103171.3	99.9
	2015	0	0	1503	68435.2	99.7
Non-tribal mothership	2002	0	0	573	26502.9	99.8
	2003	0	0	522	25332.9	97.4
	2004	0	0	569	24010.1	99.6
	2005	0	0	1038	48600.6	99.9
	2006	2	2	1243	54138.8	96.9
	2007	0	0	1135	47276.3	99.0
	2008	0	0	1346	57687.4	99.8
	2009	0	0	597	24066.4	99.5
	2010	0	0	908	35726.9	100.0
	2011	0	0	1246	49970.6	99.8
	2012	0	0	931	38042.1	98.1
	2013	0	0	1249	52348.3	99.4
	2014	0	0	1288	61793.7	98.6
	2015	0	0	625	27544.5	99.0
Tribal Mothership	2002	0	0	625	21629.0	98.7
	2003	0	0	537	19430.8	99.4
	2004	0	0	632	23511.4	100.0
	2005	1	1	632	23561.6	99.8
	2006	0	0	154	5405.4	96.3
	2007	0	0	156	5129.4	100.0
	2008	0	0	380	14977.3	99.5
	2009	0	0	403	13469.4	99.8
	2010	0	0	516	16206.2	100.0
	2011	0	0	228	6146.9	100.0
	2012	*	0	*	*	*
	2013	0	0	na	na	na
	2014	0	0	na	na	na
	2015	0	0	na	na	na

Table 6. Summary of genetic stock identification (GSI) analyses data. Table includes the observed number of green sturgeon (GSTG) from the LE and Catch Shares bottom trawl fishery during 2007-2014, and the number of GSTG bycatch tissue samples that were analyzed with GSI. GSTG bycatch samples were individually assigned to its DPS origin based on GSI: Southern DPS (SDPS) and Northern DPS (NDPS). The tissues samples from 2015 have not been processed and analyzed with GSI at the time of writing this report. The GSI data were shared by Dr. Carlos Garza at SWFSC, NMFS, NOAA.

Sector	Year	Observed GSTG bycatch	GSI analyzed samples	NDPS	SDPS	SDPS (%)
LE & IFQ Bottom Trawl	2007	6	1	0	1	100%
	2008	0	0	0	0	na
	2009	43	8	4	4	50%
	2010	8	2	0	2	100%
	2011	37	27	12	15	56%
	2012	21	18	9	9	50%
	2013	10	1	0	1	100%
	2014	39	32	21	11	34%
	2015	6	na	na	na	na
	Total	170	89	46	43	48%

Figure 1. Map of observed fishing locations (left panel) and observed green sturgeon bycatch locations (right panel) in LE and IFQ bottom trawl sectors, based on observer data during the years of 2002-2015. Observer data are aggregated to one-square-kilometer cells. Fishing locations are weighted by fishing effort, which is the landed amount of FMP-listed all groundfish species, except hake. Green sturgeon bycatch locations are weighted by number of green sturgeons in the defined spatial cells. Cells containing less than 3 vessels are not shown, to maintain confidentiality.



Appendix A

Observed and Estimated Bycatch of Green Sturgeon in US West Coast California Halibut Bottom Trawl Fishery From 2002 – 2015

Executive Summary

Fleet-wide green sturgeon bycatch estimates in the state-managed California (CA) halibut (*Paralichthys californicus*) bottom trawl fishery were derived from WCGOP observer data and fish ticket landings data (2002-2015), as described in the main section of this report. The estimated fleet-wide total bycatch of green sturgeon in this fishery is summarized in Table A1. "Bycatch" in this report is defined as the discard of green sturgeon made at sea. Since being listed under the ESA in 2006, landings and sales of green sturgeon are prohibited.

The main purpose of this report is to update the analysis of green sturgeon bycatch in the U.S. West Coast groundfish fisheries with two additional years of observer data (2014-2015). The previous biennial green sturgeon bycatch report summarized bycatch information for the years of 2002-2013 (Lee et al. 2015). Detailed analyses on the length frequencies of green sturgeon encountered, the depth distributions of hauls with green sturgeon bycatch, and the binomial model of encounter probabilities were not carried out for this status update report, because only a few additional years of data would not warrant any meaningful findings different from the ones in the previous report. If interested in detail results of those analyses, please refer to the previous biennial bycatch report (Lee et al. 2015).

Although the Biological Opinion is directed at federally-managed groundfish fisheries and does not apply to state-managed fisheries, we provide the bycatch estimates for the state-managed CA halibut fishery in this report to provide full understanding of the overall impact of NMFS-observed fisheries on green sturgeon.

It should be noted that estimates for some strata were derived from a bootstrap procedure due to confidentiality mandates. If a stratum had fewer than three observed vessels, observer data in those strata are considered confidential and cannot be reported. To effectively estimate and report the green sturgeon bycatch in those confidential strata, we applied a bootstrap procedure after pooling the strata (Table A5). The pooled strata consist of the confidential stratum itself and neighboring strata over a three-year time block (see the Methods section for further details). The estimates in those strata should be considered as a three-year running average of bycatch rates, rather than stratum-specific estimates. Thus, bycatch estimates in those confidential strata should be interpreted with caution.

During the 14-year time period, observed green sturgeon in the CA halibut fishery were exclusively encountered off San Francisco Bay, although the CA halibut fishery was observed operating in other coastal waters off CA (Fig. A1). A genetic study on green sturgeon bycatch samples from 2007-2015 (n=118) showed that 95% of green sturgeon bycatch off California likely belong to the Southern DPS (pers. comm., Dr. Carlos Garza, SWFSC, NMFS, NOAA) (Table A6). Applying this proportion of 95%, the fleet-wide bycatch estimates for Southern DPS fish in the CA halibut fishery ranged from 28 to 747 fish per year (see Table A1). We note that the genetic stock identification results are preliminary, and the genetic baseline consists of relatively few samples. Only the point estimates of DPS proportions were applied to estimate bycatch by DPS without error bounds, as these statistics were not available. Thus, these estimates should be interpreted with caution.

Introduction

All California halibut (*Paralichthys californicus*) fishing vessels are permitted and managed by the state of California, and thus outside of the federal fisheries covered by the most recent Biological Opinion (NMFS 2012). The state of California requested the WCGOP to observe the CA halibut fishery and report discarded catch, much of which is incidentally caught groundfish and thus of interest to federal groundfish fisheries. The WCGOP classifies the CA halibut fishery into two sectors: limited entry (LE) and open access (OA). Vessels in the LE sector possess both a federal LE groundfish permit and a state-issued CA halibut fishing permit. Vessels in the OA sector only possess state-issued CA halibut fishing permits. Table A2 presents a summary of the permits, gear used, target groups, vessel length range, fishing depth range, and management of CA halibut fishery sectors.

The WCGOP provides observer coverage for both of these sectors. The LE sector exists as a portion of the LE groundfish bottom trawl sector (i.e., IFQ bottom trawl since 2011), so the WCGOP isolates LE California halibut data based on the following criteria: (1) the tow target was California halibut or (2) the tow target was nearshore mix, sand sole or other flatfish, and took place in less than 30 fathoms, south of 40°10′ N latitude. All tows in the observer data set that met at least one of the above requirements were included in the LE California halibut bottom trawl dataset. The WCGOP randomly selects the fishing vessels in the OA California halibut sector separately for observer coverage. It should be noted that since 2011 the LE California halibut sector has operated under the IFQ fishery rules, with 100% observer coverage.

Methods

Bycatch Estimation

The same bycatch estimation methods and procedures described in the main section of this report were applied to WCGOP data collected from the CA halibut fishery sectors. Bycatch ratios were computed for this fishery using the observed retained weight of California halibut as the effort metric (i.e., the denominator). The fleet-wide landed weight of California halibut was then used as a multiplier (i.e., expansion factor) to expand the estimated green sturgeon bycatch to the fleet level.

Fleet-wide discard estimates in the California halibut bottom trawl fishery were derived from WCGOP observer data and fish ticket landings data. All California halibut vessels are permitted by the state of California. However, limited entry (LE) California halibut vessels also have a federal limited entry groundfish permit, whereas open access (OA) vessels do not. For a description of the California halibut bottom trawl fishery, vessel selection, observer coverage, vessel waivers, and prior California halibut bottom trawl reports, see: http://www.nwfsc.noaa.gov/research/divisions/fram/observation/data_products/halibut_trawl.cfm

The LE and OA components of the CA halibut trawl fishery remain separate as independent sectors in this report. Thus, bycatch ratios and fleet-wide total bycatch numbers were estimated independently by each sector (Table A3). However, for the years 2011-2015, fleet-wide total bycatch is reported as a combined sum of both sectors even though estimations were done independently by sector (Table A4). Fishing activity by < 3 observed vessels in a

stratum is confidential, so the LE component could not always be reported independetnly. Similarly, we were unable to report bycatch by seasonal strata for 2011-2015 in order to maintain confidentiality issues in the LE sector. The portions of unsampled categories of the LE sector during 2011-2015 were estimated by the same method as described in the main section of this report for the IFQ bottom trawl sector.

Confidence intervals of bycatch ratios and fleet-wide total bycatch estimates for each stratum were estimated using the same bootstrap procedure as described in the main section of this report. There were several confidential strata in both the LE and OA sectors, which prevent us from reporting observed bycatch numbers and associated fishing-trip related information directly. Therefore, we pooled these data across a three-year time window around the confidential stratum as described in the main section of this report. If an adjacent stratum was unobserved, then the available data from the next closest year-season stratum was included in the pool so that at least 3 years were used (Table A5). The bycatch ratio and its 95% confidence limits for the confidential stratum were estimated from the bootstrapped distribution with average, 2.5% and 97.5% percentiles, respectively. Bycatch ratios in these confidential strata can be regarded as a three-year running average. Although the bycatch ratio for a confidential stratum was estimated based on a pooling strategy across the strata of adjacent years, the total landed weight of CA halibut (i.e., expansion factor) of the confidential stratum itself was used as the multiplier for expansion to estimate the fleet-wide total bycatch for that confidential stratum.

When green sturgeon are encountered on vessels, observers document fish length (in fork length), weight, and general condition, take photographs, scan for scute markings and tags, insert a PIT (passive integrated transponder) tag if not already tagged, and take a tissue sample. If the specimen is obviously dead, the observer will also take a fin ray sample and determine sex (NMFS 2017). For a subset of the green sturgeon observed and released alive in 2015 and 2016, observers also applied a satellite tag to the fish as part of a post-release survival study.

Results

Bycatch Estimation

WCGOP data suggests the extent to which the observed CA halibut fishery operated in CA coastal waters between 2002-2015 (Fig. A1). The clusters of CA halibut fishing areas are found off San Fransisco Bay and its coastal areas, Monterey Bay, Morro Bay, and Santa Barbara coasts. The fishing effort used for mapping did not include any logbook information or any unobserved fishing trips. While fishing efforts for CA halibut dispersed along the CA coast, the observed green sturgeon were exclusively encountered in an area off San Francisco Bay during those observed fishing trips.

Summaries of green sturgeon bycatch and associated statistics in the CA halibut fishery sectors, estimated based on WCGOP data, are provided in Table A3 for 2002-2010 and in Table A4 for 2011-2015. Annual fleet-wide bycatch estimates fluctuated between 0 and several hundred in the LE and OA sectors. The highest observed bycatch was 108 green sturgeon in winter of 2006 in the LE sector, which resulted in a fleet-wide total bycatch estimate of 786 green sturgeon (Table A3). Between 2002 and 2010, the LE sector encountered more green sturgeon than the OA sector when expanded to fleet-wide level. When analyzing annual green

sturgeon bycatch combined across sectors and seasons, there was an increasing trend in the annual fleet-wide total bycatch estimates from 2002-2006. After 2006, the annual fleet-wide total bycatch estimates declined due to fewer observed encounters in the OA sector from 2007 to 2012. However, observed bycatch sharply increased in 2013, and resulted in the 4th highest (526 in 2013) and the 2nd highest (664 in 2015) annual fleet-wide total bycatch estimate over the period of 2002-2015 (Table A4).

The extent of observer sampling rates differed by fishery sectors and changed from year to year. Observer sampling rate is defined as the percent of observed fishing effort (i.e., observed landed weight of CA halibut catch) relative to total fishing effort (i.e., fleet-wide landed weight of CA halibut). Sampling rates for the LE sector during 2002-2010 ranged between 5.2% and 39.8%, with an average of 18.4%, not including unobserved and confidential strata. Since 2011, sampling rates for the LE sector are near 100%, due to the IFQ requirement of observer coverage on all fishing trips. Sampling rates of the OA sector were relatively low during 2002-2013 (range: 2.5% to 25.5%), with an average of 8.6%, not accounting for unobserved and confidential strata. However, sampling rates in 2014 and 2015 were substantially increased by the WCGOP to 22.3% in 2014 and 33.3% in 2015 in an effort to enchance the coverage and to improve the precision of fleet-wide bycatch estimation in the OA sector.

Beginning in 2011, the LE sector of CA halibut fishery, as part of the IFQ bottom trawl fishery, has received 100% observer coverage (i.e., all fishing trips had an observer). For the period from 2011-2015, all catches were sampled, except in 2011 (99.99%). The unsampled portion in 2011 was expanded based on the method described in the main section of this report. Because the unsampled catch portion in 2011 was very small, the expansion did not affect the total green sturgeon bycatch estimate in that stratum.

It should be noted that the landed amount of CA halibut has declined in the LE sector under the IFQ program since 2011, resulting in no landings in 2014 and 2015. Because LE is a part of the IFQ program with 100% observation, the uncertainty measure (i.e., 95% confidence limits) around the fleet-wide total bycatch estimates for 2011-2015, presented as combined estimates across the two sectors, was affected only by the OA portion.

Discussion

During the observed trips by the WCGOP for the years of 2002-2015, green sturgeon were exclusively encountered by the CA halibut fishery in a confined coastal area off San Francisco Bay. The annual fleet-wide bycatch estimates for green sturgeon ranged from 45 to 786 fish from 2002-2010 and from 29 to 664 fish from 2011-2015 (Table A1). Even though the CA halibut fishery is not covered by the Biological Opinion for the federal groundfish fisheries, the CA halibut fishery bycatch estimates are included in this report as an appendix to provide information on green sturgeon bycatch in all of the fisheries observed by the WCGOP.

When green sturgeon were encountered in the CA halibut fishery, about 60% of the time only one fish was encountered per haul, and it was very rare that more than 4 green sturgeons were encountered per given haul until 2014 (Lee et al. 2015). However, in 2015 there were two hauls from one trip that encountered unusually large numbers of green sturgeon per haul, 25 and 27. This unusual encounter of such large numbers of green sturgeon in a few hauls may be due to

a purely random event, due to increases in observer coverage, or due to a possible increase in the abundance of green sturgeon in the fishing ground. It is unknown at this point what factors are associated with such large bycatch events in a few hauls. Additional years of observer monitoring at the expanded level of observer coverage (> 30%) and other cooperative research efforts, would shed light on this question of unusually high encounter events and the factors associated with green sturgeon bycatch.

Table A1. Summary of expanded fleet-wide bycatch estimates of green sturgeon in the LE and OA CA halibut fisheries that were observed by the WCGOP. For 2011-2015, bycatch numbers are reported as combined (RAC) between the sectors due to confidentiality mandates. Double dashes (--) signify strata with no observer coverage. Estimates of Southern DPS (SDPS) bycatch are calculated based on genetic stock proportion (95%) of green sturgeon in CA waters.

	Sector		SDPS (95%)		Totals	
Year	LE	OA	LE	OA	Both DPS	SDPS
2002	185	--	175.8	--	185	176
2003	360	74	342.0	70.3	434	412
2004	200	178	190.0	169.1	378	359
2005	505	147	479.8	139.7	652	619
2006	786	--	746.7	--	786	747
2007	103	0	97.9	0.0	103	98
2008	175	0	166.3	0.0	175	166
2009	45	0	42.8	0.0	45	43
2010	155	0	147.3	0.0	155	147
2011	RAC		RAC		29	28
2012	RAC		RAC		79	75
2013	RAC		RAC		526	500
^2014	RAC		RAC		121	115
^2015	RAC		RAC		664	631

^ bycatch occurred only in OA sector, due to no CA halibut landings in LE sector.

Table A2. Generalized descriptions of CA halibut fisheries that have had observed bycatch of green sturgeon.

							Management	
Sector	**Sub-Sector**	**Permits**	**Gear(s)**	**Target(s)**	**Vessel length (m)**	**Depths (m)**	**2002-2010**	**2011-2015**
Limited Entry (LE) California Halibut Trawl	None	CA Halibut permit and LE permit with trawl endorsement	Bottom trawl	California Halibut	9–22	< 55	Cumulative two month trip limits; depth-based closures; 3-23% observer coverage	Individual Fishing Quotas (IFQ); 100% observer coverage
Open Access (OA) California Halibut Trawl	None	LE permit with MSCV endorsement	Bottom Trawl	California Halibut	3–30	< 55	Most fishing occurs within CA waters in the California Halibut Trawl Grounds where minimum mesh sizes, seven month season, and minimum size requirements hold; 0-33% observer coverage	

Table A3. Observed bycatch numbers, bycatch ratios, and fleet-wide total bycatch numbers of green sturgeon from California halibut bottom trawl fishery (2002-2010), separated by limited entry (LE) and open access (OA) sectors. Bootstrapped confidence intervals (95% CI) are provided for the estimates. CA halibut landings are in metric tons (MT). Winter season is January-April and November-December; summer is May-October. Bycatch ratios in the shaded strata were derived from a bootstrap procedure, as explained in the Methods. Asterisks (*) signify strata with fewer than three observed vessels. Double dashes (--) signify unobserved strata.

Sector	Year	Season	Observed bycatch	Observed CA halibut landings (MT)	Fleet-total CA halibut landings (MT)	CA halibut landings sampled (%)	Bycatch ratio	Lower CI of ratio	Upper CI of ratio	Fleet-total bycatch	Lower CI of bycatch	Upper CI of bycatch
LE	2002	winter	1	3.6	68.8	5.2	0.28	0.00	0.36	19	1	25
		summer	*	*	36.4	*	4.54	1.51	6.64	166	56	241
	2003	winter	2	12.9	61.9	20.8	0.16	0.00	0.23	10	2	14
		summer	50	6.2	43.6	14.3	8.03	1.54	12.13	350	68	530
	2004	winter	1	14.7	79.9	18.4	0.07	0.00	0.23	5	1	19
		summer	58	16.8	56.5	29.8	3.45	0.00	6.51	195	58	369
	2005	winter	18	10.7	131.4	8.2	1.68	0.00	14.33	220	18	1884
		summer	98	19.8	57.4	34.4	4.95	1.77	6.04	285	98	347
	2006	winter	108	11.1	80.6	13.7	9.75	2.18	14.75	786	178	1194
		summer	0	3.2	38.9	8.3	0.00	na	na	0	na	na
	2007	winter	6	3.0	27.4	11.0	2.00	0.00	3.51	55	6	96
		summer	10	2.4	11.8	20.8	4.09	0.00	5.36	48	10	63
	2008	winter	44	9.5	34.0	27.9	4.58	3.24	9.12	158	110	311
		summer	1	0.1	2.4	5.6	7.60	0.00	7.93	18	1	19
	2009	winter	--	--	39.9	--	--	--	--	--	--	--
		summer	18	2.9	7.3	39.8	6.21	5.88	6.87	45	43	50
	2010	winter	*	*	32.8	*	3.52	0.83	7.15	114	27	235
		summer	*	*	21.2	*	0.98	0.33	3.62	41	10	105
OA	2002	winter	--	--	21.6	--	--	--	--	--	--	--
		summer	--	--	14.2	--	--	--	--	--	--	--
	2003	winter	*	*	18.5	*	3.14	0.21	9.61	58	4	172
		summer	4	1.8	7.3	25.5	2.16	0.00	6.48	16	4	47
	2004	winter	2	0.9	29.6	3.1	2.20	0.00	4.28	65	2	127
		summer	*	*	41.3	10.2	2.73	0.00	6.38	113	0	263
	2005	winter	6	2.0	24.1	8.5	2.94	0.00	16.85	71	6	406
		summer	*	*	40.4	13.5	1.92	0.00	3.94	76	27	159
	2006	winter	--	--	18.4	--	--	--	--	--	--	--
		summer	--	--	36.4	--	--	--	--	--	--	--
	2007	winter	0	0.8	8.2	9.5	0.00	na	na	0	na	na
		summer	0	1.9	30.9	6.2	0.00	na	na	0	na	na
	2008	winter	0	0.8	21.2	4.0	0.00	na	na	0	na	na
		summer	0	1.8	30.3	5.8	0.00	na	na	0	na	na
	2009	winter	*	*	37.4	*	0.00	na	na	0	na	na
		summer	*	*	44.9	*	0.00	na	na	0	na	na
	2010	winter	0	0.7	28.0	2.5	0.00	na	na	0	na	na
		summer	0	1.7	41.5	4.0	0.00	na	na	0	na	na

Table A4. Observed bycatch numbers and fleet-wide total expanded numbers of green sturgeon bycatch from California halibut bottom trawl fishery (2011-2015), as combined from limited entry (LE) and open access (OA) sectors. Estimates for each sector were calculated separately and then summed to generate the fleet-wide total expanded bycatch estimates across both sectors. The low number of vessels that participated in the LE sector (< 3 vessels per year) resulted in the need to combine the LE and OA sectors bycatch estimates and not report LE landings to maintain confidentiality. Since 2011, the LE sector has been observed at 100% as a part of the IFQ program. Landings for the OA sector are given in metric tons.

Year	LE + OA combined observed bycatch	LE + OA combined fleet-total bycatch	Lower CI of fleet-total bycatch	Upper CI of fleet-total bycatch	Coverage			
					Limited Entry	Open Access		
					CA halibut landings sampled (%)	Observed CA halibut landings (MT)	Fleet-total CA halibut landings (MT)	CA halibut landings sampled (%)
2011	13	29	16	35	100	12.4	79.9	15.6
2012	6	79	11	136	100	3.5	55.3	6.4
2013	46	526	228	976	100	4.3	68.9	6.3
^ 2014	27	121	62	870	na	18.1	81.4	22.3
^ 2015	221	664	490	2352	na	30.6	92.0	33.3

^ bycatch occurred only in OA sector, due to no CA halibut landings in LE sector.

Table A5. Confidential strata (asterisks) and neighboring strata (shaded) that were pooled for bootstrapping. Bycatch rates in the confidential strata were estimated based on a bootstrap procedure, which was applied to the pooled strata.

			Confidential Strata							
Sector	Year	Season	LE 2002 summer	LE 2010 winter	LE 2010 summer	OA 2003 winter	OA 2004 summer	OA 2005 summer	OA 2009 winter	OA 2009 summer
LE	2002	winter								
		summer	*							
	2003	winter								
		summer								
	2004	winter								
		summer								
	2005	winter								
		summer								
	2006	winter								
		summer								
	2007	winter								
		summer								
	2008	winter								
		summer								
	2009	winter	--	--	--	--	--	--	--	--
		summer								
	2010	winter		*						
		summer			*					
	2011	winter								
		summer								
OA	2002	winter	--	--	--	--	--	--	--	--
		summer	--	--	--	--	--	--	--	--
	2003	winter				*				
		summer								
	2004	winter								
		summer					*			
	2005	winter								
		summer						*		
	2006	winter	--	--	--	--	--	--	--	--
		summer	--	--	--	--	--	--	--	--
	2007	winter								
		summer								
	2008	winter								
		summer								
	2009	winter							*	
		summer								*
	2010	winter								
		summer								

Table A6. Summary of genetic stock identification (GSI) analyses data. Table includes the observed number of green sturgeon (GSTG) from the CA halibut fishery during 2007-2014, and the number of GSTG bycatch tissue samples that were analyzed with GSI. The GSTG bycatch samples were individually assigned to its DPS origin based on GSI: Southern DPS (SDPS) and Northern DPS (NDPS). The tissues samples from 2015 have not been processed and analyzed with GSI at the time of writing this report. The GSI data were shared by Dr. Carlos Garza at SWFSC, NMFS, NOAA.

Sector	Year	Observed GSTG bycatch	GSI analyzed samples	NDPS	SDPS	SDPS (%)
LE & OA Calif. Halibut	2007	103	9	1	8	89%
	2008	175	23	3	20	87%
	2009	45	17	2	15	88%
	2010	155	0	0	0	na
	2011	29	8	0	8	100%
	2012	79	4	0	4	100%
	2013	526	33	0	33	100%
	2014	121	24	0	24	100%
	2015	664	na	na	na	na
	Total	1898	118	6	112	95%

Figure 1. Map of observed fishing locations (top panel) and observed green sturgeon bycatch locations (bottom panel) in LE and OA California (CA) halibut trawl sectors, based on WCGOP data during the years of 2002-2015. Observer data are aggregated to one-square-kilometer cells. Fishing locations are weighted by fishing effort, which is the landed amount of CA halibut. Green sturgeon bycatch locations are weighted by number of green sturgeons in the defined spatial cells. Cells containing less than 3 vessels are not shown, to maintain confidentiality.